WLAN PROTOCOL AND NETWORK ARCHITECTURE IDENTIFICATION FOR SERVICE MIX APPLICATIONS

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Abstract - This paper proposes an algorithm approach to examine the impact of using different application services with various IEEE technologies in order to identify the optimum technology among different network architectures;Basic Service Set (BSS), Extended Service Set (ESS), and the Independent Basic Service Set (IBSS).Specifically, we utilize an algorithmic and mathematical scheme to allow user/client to analyse the optimum WLAN technology and network architecture's performance to be used for a given mix of internet applications configured across three spatial distributions (circular, uniform, random).Moreover, the proposed algorithm considers multi-criteria access network selection such as spatial distribution and number of nodes, hence to facilitate the provision of the best overall network performance and high-quality services. For further throughput enhancement, we adopt the Quality of Service (QoS) metrics for each application to develop a computational algorithm model to provide precise numerical results used to rank and identify the optimum overall performance's technologies. Our numerical results corroborate the analytical framework results and demonstrate the strength of the proposed algorithm.

Keywords - VoIP, Video Conferencing, IEEE technologies, Performance Analysis, QoS.

I. INTRODUCTION

Wireless networks have been designed to provide provision for real-time applications such as voice over IP (VoIP) and video conferencing (VC) as well as for best-effort services such as e-mail, file transfer (FTP) and Web (HTTP). Wireless LAN (WLAN) connects people and allow to access information over a distance without cables; it operates in an air interface. WLAN networkshave become one of the fastest growing sectors of the communication industry, due to their low cost and ease of deployment as well as maintenance. The degree of freedom in movement and ability to spread services to various parts of homes or/and business infrastructure, there is a rapid interest towards WLAN networks, as it is currently considered vital to implement in real-time operations[1]. Internet-based services such as web, email and file transfers affect the usage of WLANs in addition to voice over wireless networks. Real-time applications as VoIP enables users to use the Internet as a transmission medium by sending voice data in packets using Internet Protocol (IP) rather than by traditional circuit-switched Public Switched Telephone Network (PSTN).In WLANs where a mix of applications have been deployed, a number of factors that affect the network performance should be addressed and evaluated such as the wireless network architectures (BSS, ESS and IBSS) and IEEE MAC-layer technologies [2]. Moreover, as demonstrated in [3] the optimum performance of IEEE technologies deployed in real-time industrial communication systems not always guaranteed to recent technologies (802.11n) over the older one (802.11g), for this exact reason our work provides analyzing study that suggests to the user/client the optimum technology/technologies and network architecture without wasting resources nor getting in the issues of randomly choosing specific technologies then redesigning the whole configuration.

However, providing precise QoS is considered as an issue for wireless networks in the existence of application mixes andhas been the object of wide research [4]–[6]. Firoiu [4] produced a novel architecture realized with a combination of scheduling and queue management mechanisms that classify WEB/TCP traffic as the drop-conservative queue achieving a lower loss, and VoIP/UDP traffic is scheduled into the delay-conservative queue, achieved a shorter delay.

The article by Wei et al. [5] studied the performance of HTTP and FTP protocols under the same network environment for five clients. The study was conducted using two metric parameters average queuing delay and TCP delay and showed that the performance of the HTTP protocol is better than the FTP protocol. Seytnazarov and Kim [6] showed that in order for real-time services to work adequately, the QoS parameters and characteristics performance have to be fulfilled and demonstrated that on the 802.11n network configured over 20 nodes the total throughput decreased.

Many researches have been produced to evaluate the applications for QoS metric parameters that are configured over IEEE technologies [7]–[9]. Mehmood and Alturki [7] introduced an architecture that analysed an IBSS network for a mix of HTTP, voice and video applications over 802.11g technology to scale and provisions QoS. This architecture scales well with an increase in the network size and outperforms well-known routing protocols. AlAlwai and Al-Aqrabi [8]Evaluated the performance of VoIP in 802.11 wireless networks for 3-15 nodes in the ESS networks environment.Pérez et al. [9] introduced a scenario to evaluate IEEE 802.11e standard for a number of videos, voice and best effort nodes, varying from 5 to 45 nodes, and showed an increase in average delay for these services.

II. PRELIMINARIES

A. IEEE MAC Layer Technologies

The Institute of Electrical and Electronics Engineers (IEEE) developed the 802.11 family as a technology for WLAN technology. IEEE 802.11b support operation in the unlicensed 2.4 GHz instrumentation, scientific and medical (ISM) band with a maximum transmission rate of 11 Mbps.IEEE 802.11a support networks in the 5 GHz ISM band and provides a transmission speed of 54 Mbps [10]. In 2003, IEEE 802.11g supports transmission speeds of up to 54 Mbps by applying Orthogonal Frequency Division Multiplexing (OFDM) in the 2.4 GHz band. IEEE 802.11 standard does not support time-sensitive voice applications but only best-effort services. After several refinements and with the increasing call for real-time applications, a new amendment named IEEE 802.11e was designed to improve Quality of Service (QoS) [11].

B. IEEE Network Infrastructures

IEEE 802.11 defines two basic modes of communication between WLAN nodes: Infrastructure and Independent which are known as Ad Hoc Networks [12].

Infrastructure BSS is a group of stations that connect to the same wireless medium and are controlled by a centralized coordination function or access point (AP). All stations can communicate directly with all other stations in a fixed range of the base station. The IEEE 802.11 infrastructure networks use APs. AP supports wave extension by providing the integration points necessary for network connectivity between multiple BSSs, thus forming an Extended Service Set (ESS). In addition, the IBSS or Ad-hoc network is a specified group of nodes in a single BSS for the purpose of internetworking without the aid of a centralized coordination function [13] (i.e. access point).

C. QoS Performance Metrics and Importance Coefficient for Real-time Applications

Performance metrics are defined in terms of QoS metric parameters for real-time and best-effort applications. For each application, a satisfaction criterion (acceptable threshold) for each QoS metric parameter is identified [14], [15] as shown in Table I, which represents the key QoS requirements and recommendations for each application (bearer traffic).

Application	Importance & Threshold	Delay (sec)	Jitter (sec)	Throughput (kbps)	Racket Loss Rate (%)
VoIP	Importance	H	H	M	L
	Threshold	0.15	0.04	45	5
VC	Importance	H	H	H	M
	Threshold	0.15	0.03	250	1
HTTP	Importance	M	VL	L	L
	Threshold	1	0	30	10
FTP	Importance	L	VL	M	H
	Threshold	1	0	45	5
E-mail	Importance	L	VL	L	L
	Threshold	1	0	30	10

TABLE I QoS Metric Parameters Importance for Applications

The applications' qualities are directly affected by the following QoS metric measurements:

- Packet End-to-End delay (sec): the time is taken by data/voice to travel from node A to node B on the network.
- Jitter (sec): the variance in delay caused by queuing.
- Throughput (bit/sec): the total rate at which packets are transferred from the source to the destination at a prescribed time period.
- Traffic Sent (packet/sec) and Traffic Received (packet/sec): used to calculate packet loss rate, which is the percentage of packets that get lost along the communication path after the packet is transmitted by the sender into the network.

It is worth noting that an important coefficient is assigned to each application parameters (IAP) in terms of its impact on the data quality of the service. Table I shows the QoS qualitative importance of each QoS parameter and their related threshold values for each application. In order to be able to account for these qualitative factors in a simulation they have to be translated into numbers (H=1, M=0.5, L=0.1, and VL=0).

III. PROPOSED ALGORITHM: PROTOCOL AND NETWORK ARCHITECTURE SELECTION

A. Building Projects (Simulation Environment)

In this paper, an OPNET simulation platform [16] is used to build and analyse all applications scenarios. Using OPNET Modeller, we have considered two main inputs for the user configuration stage, these are: the number of nodes and Service Mix of applications. Fig. 1. Illustrates the main factors of this algorithm. System specification defines the environmental aspects that will be studied and analysed to build many different scenarios: network architectures, spatial distributions and QoS metrics.

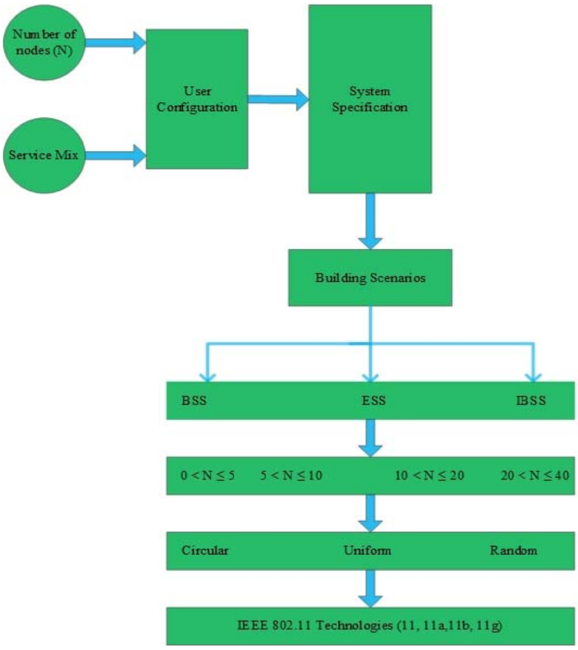
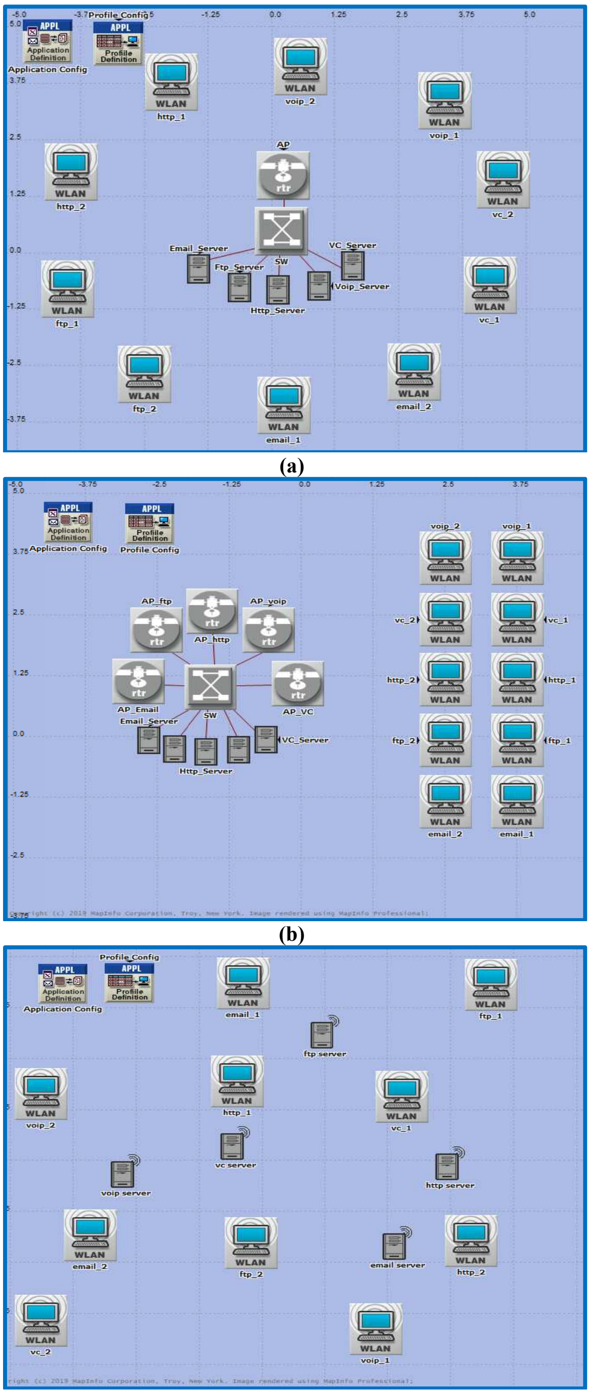


Fig. 1 Flowchart of the proposed algorithm

Network architectures specify how different wireless components connect together in either of two modes: the presence of access points (BSS and ESS) mode or the absence of access points (IBSS) mode, spatial distribution which specifies the topology in which these nodes will be distributed – in a circular (oval) way, uniform (grid) way, or randomly scattered way, number of nodes needed in this network which breaks down to four groups (0-5, 6-10, 11-20 and 21-40). IEEE MAC Technologies defines the physical layer technologies that will be used to build many different scenarios. Each group of nodes (5, 10, 20, and 40) in the three network architectures is configured with the following applications mixes across all three spatial distributions:20% for each application (VoIP, VC, HTTP, FTP and E-mail).

All network architectures (BSS, ESS, IBSS) have been configured and implemented across all three spatial distributions (circular, uniform, random) for the four groups of nodes.Figs. 2(a), (b) and (c) show some of these implemented scenarios. The real-time applications' settings for the simulation run which lasted for 20 minutes, the VoIP traffic has been configured with the following parameters: voice frame per packet is 1, the encoder scheme is G.711, traffic type is an interactive voice. In addition, the VC traffic parameters configuration is: the frame interarrival time is 15 frame/sec and frame size information of 128x240 pixels (bytes). On the other hand, HTTP 1.1 is used along with 50 KB FTP file size and 1 KB E-mail size.



(a)

(b)

(c)

Fig. 2. Design of the three Network Architectures across three Spatial Distributions for Service Mix
(a) Basic Service Set (BSS), (b) Extended Service Set (ESS), (c) Independent Basic Service Set (IBSS)

B. System Model's Calculation

The system calculations and the mathematical model are shown in Fig. 3. The inputs for the algorithm's mathematical calculations are QoS Threshold values for each application and Cumulative Distribution Function (CDF). Applications QoS Threshold values (satisfaction criterion) are taken from literature as shown in Table I [14], [15].

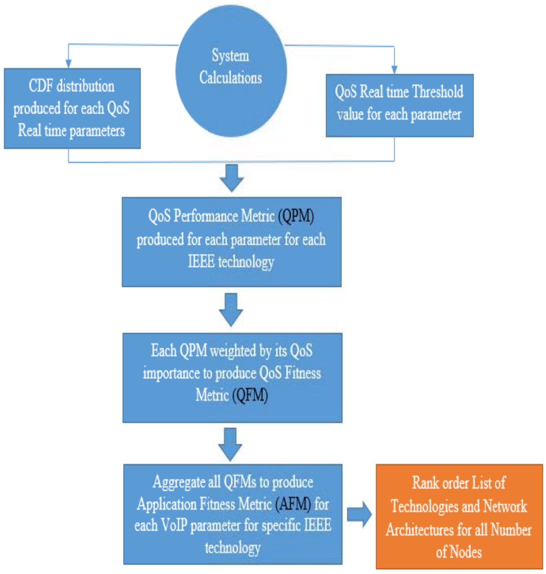


Fig. 3Algorithm's calculations flowchart

CDF distribution is produced for these QoS metric parameters from OPNET after running the simulation scenarios. Mathematical calculations will be done to determine how a particular scenario has satisfied certain performance metrics for each application. The following steps are used to explain the calculations of this algorithm and to analyse the results for each of the above projects:

- QoS Performance Metric (QPM): as Fig. 4 illustrates, the value that is produced by applying the application QoS metric Parameter Threshold Value (PTV) for each QoS performance criterion n once is represented in CDF distribution F(n), which is given by (1).

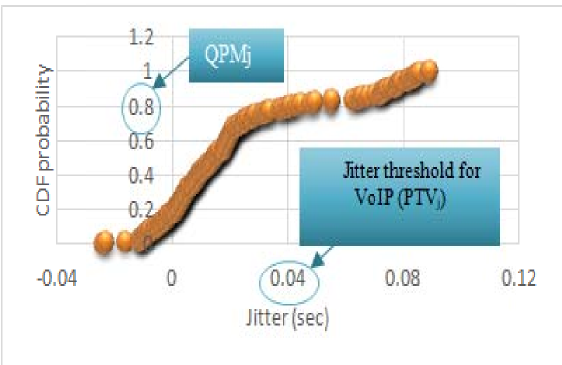


Fig. 4 QPM for jitter

- QoS Fitness Metric (QFM): the value that is produced by applying a weighting to the QPM (assigned by importance) for each QoS metric parameter (H=1, M=0.5, L=0.1 and VL=0) is expressed by (2).
- The final step will be calculating the Application Fitness Metric (AFM) which is to aggregate all QFMs for n application QoS metric parameters (delay, jitter, throughput and packet loss), for each IEEE 802.11 technology j, as demonstrated by (3). This is to show that each QoS application metric has its importance and impact on the provided service and should not be ignored through the process of identifying the optimum IEEE technology performance for certain application parameters.
- Based on AFMs of the IEEE 802.11 technologies, the rank order of these five technologies will be produced for each of the three built network architectures. Hence, the best network architecture performance will be identified for all groups of nodes.

As explained previously, CDF distribution F(n) [17] is going to be produced for all applications QoS metric parameters from the OPNET Modeler simulation, then analysed against PTV as follows:

1. If ptv∈F(n): it means that the PTV has a specific value on its CDF distribution equal to QPM for this metric parameter. QPM is weighted by IAP to produce QFM. Then the aggregation of all QFMs yields AFM which is used to classify IEEE technologies.
2. If ptv > F(n): it means that the QPM value equals 1 and QFM has arisen.
3. If ptv<F(n): it means that the QPM value equals 0 and QFM will be initialized.

The value generated for the applications QoS metric parameters (jitter, delay, throughput and packet loss) will contribute rank order of IEEE technologies for each network architecture.

A code has been programmed using MATLAB software to develop a method to calculate the packet loss percentage for each application. This method is linked directly with the OPNET Modeler to produce a specific packet loss percentage for each application. Application packet loss rate ω_i of a node iis the ratio of dropped voice packetk_i to total voice packets$\rho_i$multiplied by 100%, as demonstrated by (4). This requires the traffic received/send rate values from OPNET Modeler to be integrated to produce the total number of packets received and sent. Then, the exact packet loss ratio is produced and should be presented as a CDF diagram to enable identification of the values of QPM, QFM and AFM using the previously explained flowchart.

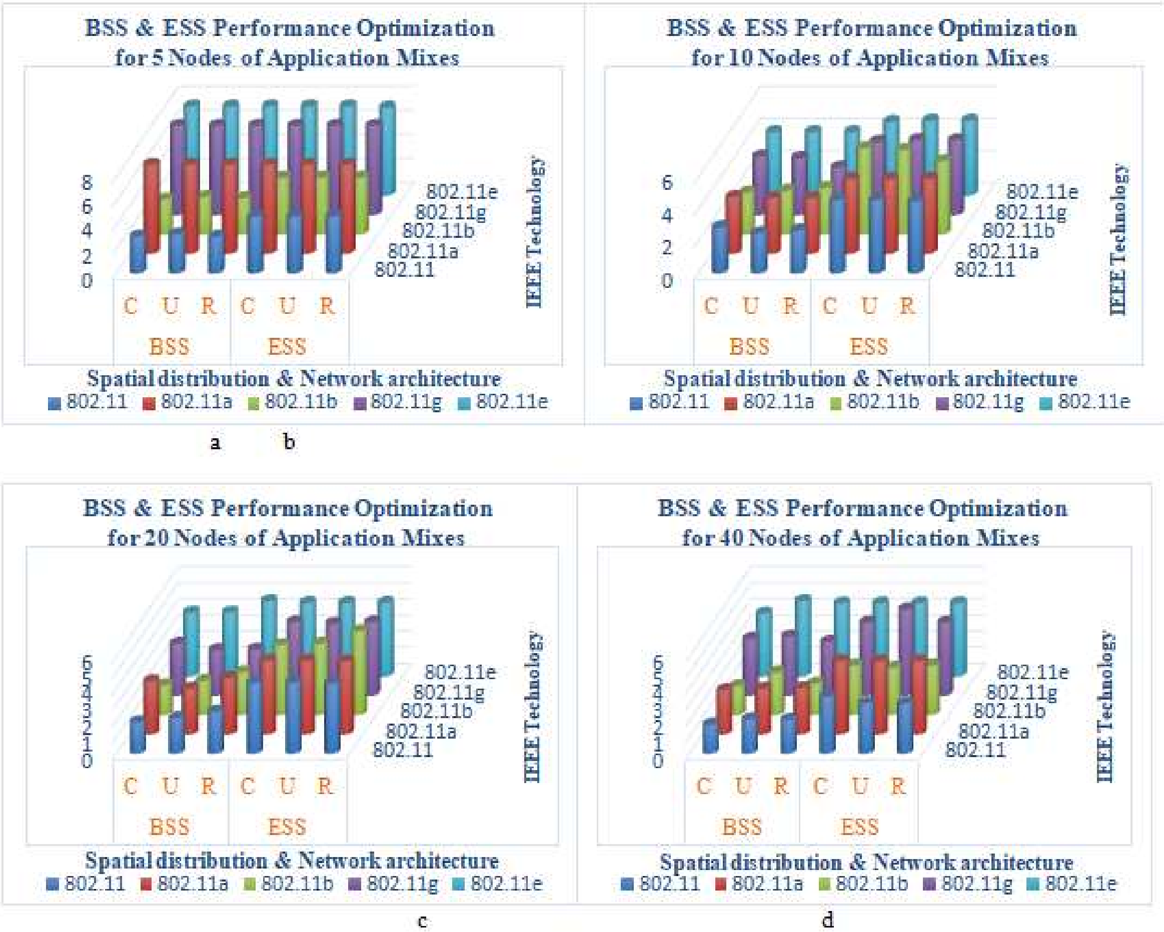


Fig. 5. BSS & ESS Performance Optimization for various nodes.
(a) 5 nodes, (b) 10 nodes, (c) 20 nodes, (d) 40 nodes

Identical calculation steps were applied for the other three groups of nodes (0-5, 11-20 and 21-40), to ascertain the best performing IEEE technology/technologies and to produce all values of QPMs, QFMs, and AFMs for all QoS metric parameters regarding each application in all network architectures across the three spatial distributions.

IV. RESULTS AND PERFORMANCE EVALUATION

In this article, the output of the proposed algorithm identifies the options available for a client (user) based on the tables of the results that have been produced for all scenarios across three network architectures. All simulated scenarios are applicable to the lab (room) sizes from 2x3m to 10x14m.

The format of the results is demonstrated based on the presence of an access point; therefore, the tables of the results are interpreted (translated) as: generic results and IBSS only, as will be demonstrated in Figs. 5 and 6, respectively.

- In case there is at least one access point in the network, then the proposed algorithm in Fig. 1 and the result in Fig. 5 will be applied. This case is applicable to both infrastructure architecture layers (ESS and BSS).
- If the network is configured without any access points, then the proposed algorithm in Fig. 1 and the IBSS result's described in Fig. 6 will be used.

Based on the user's configuration and the number of nodes required to set up the designated network, both results' charts classify four key groups of nodes, presented as follows:

1. The first category, where $5 \geq N > 0$, in the generic result, as can be seen in Fig. 5(a), if the client is going to build a small network (number of nodes less than or equal to five nodes), then both ESS or BSS providesthe optimum performance across all threespatial distributions if they are implemented usingonly three technologies including 802.11a, 11g, and 11e. In the case of the IBSS result's chart, the technologies 802.11a, 11g, and 11e remain the optimum across all spatial distributions as shown in Fig. 6(a).
2. As shown in Fig. 5(b), when $10 \geqslant N > 5$, if the client is implementing a network using a number of nodes between 5 and 10, then ESS provide

optimum performance.IEEE 802.11a technology performs the ideal technology if the network is only configured in circular and uniform distributions. In the case of the IBSS results, the 802.11eproduces the optimum performance if it is only configured in uniform and random distributions as demonstrated in Fig.6 (b).

3. The third category, where $20 \geq N > 10$, if the client is going to build a medium-size network with the number of nodes from 10 to 20, then ESS provide the optimum performance. Almost all technologies produce similar performance across all three spatial distributions as shown in Fig. 5(c). However, according to the IBSS result, the IEEE 802.11e is the optimum technology to be used across all three distributions as shown in Fig. 6(c).
4. In the fourth category, where $40 \geqslant N > 20$, the best architecture for this large network is ESS. Subsequently, the client has a number of options to select according to the information providedin Fig.5 (d). First, IEEE 802.11g is the optimum technology to be used across three distributions, However,it yields the highest performance if the network is only configured uniformly; while the second-best option is to use both technologies 802.11a and 11e across all three distributions. On the other hand, in the IBSS result, IEEE 802.11e is acknowledged as the preferable solution as demonstrated in Fig. 6(d).

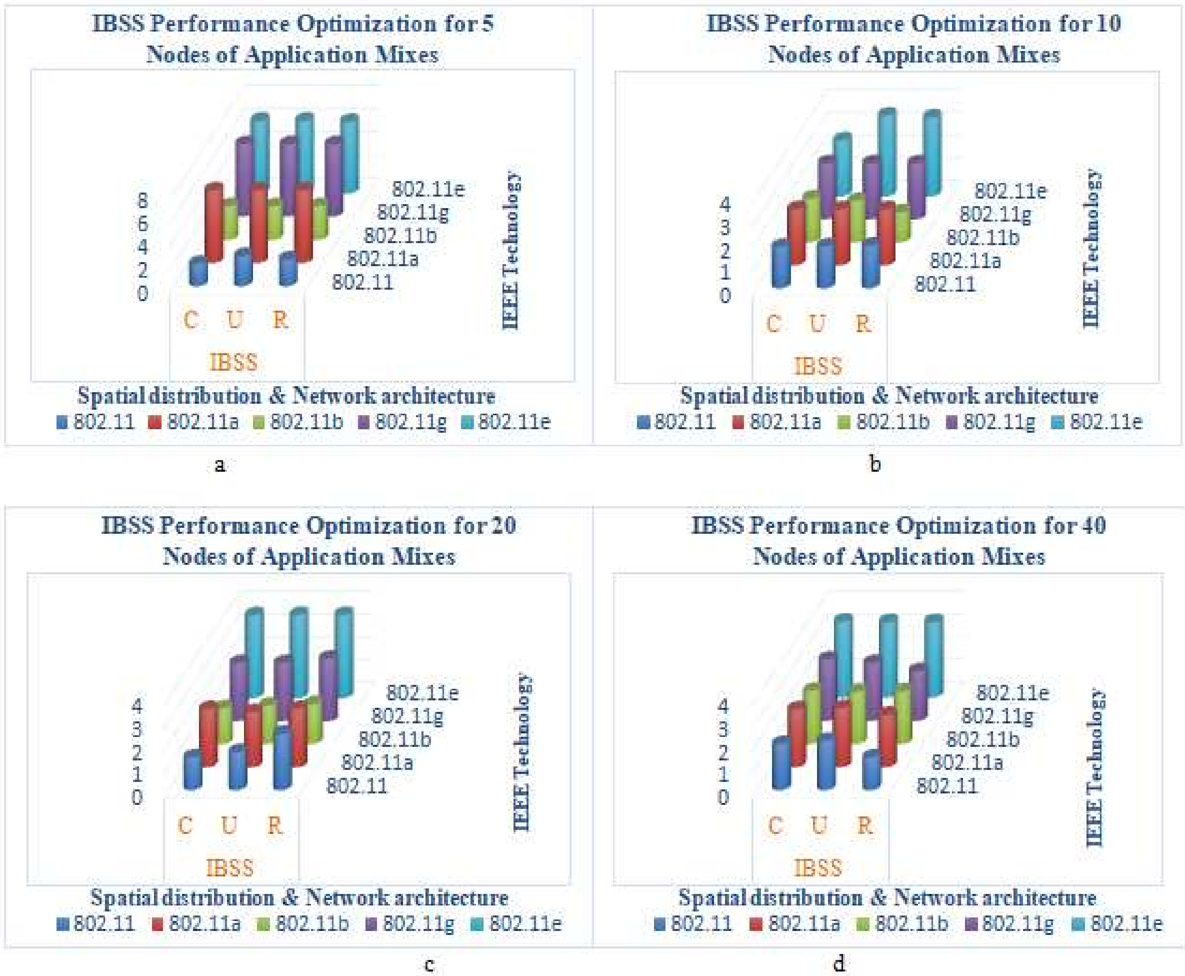


Fig. 6. IBSS Performance Optimization for various nodes.
(a) 5 nodes, (b) 10 nodes, (c) 20 nodes, (d) 40 nodes

V. CONCLUSION

In this paper, the rank order of different IEEE 802.11 technologies has been produced across different spatial distributions for a 20% mix of internet applications (VoIP, VC, HTTP, FTP and E-mail). Number of nodes needed in this network which breaks down to four groups (0-5, 6-10, 11-20 and 21-40). IEEE MAC Technologies defines the physical layer technologies that will be used to build many different scenarios.

The results of application mixes show that it is only preferable to use the ESS network with a high number of workstations/nodes; this is due to the high packet loss and delay that might appear in the network owing to the increase in the number of workstations. Furthermore, IBSS can be worked efficiently with 802.11ectechnology for almost all selected numbers of nodes. On the other hand, BSS performance is degraded when the number of nodes is more than twenty. Furthermore, the results of VoIP show IBSS can be worked efficiently with the 802.11a, 802.11g and 802.11e technologies that implement the Orthogonal Frequency Division Multiplexing (OFDM) modulation technique, which uses subchannels to transmit different signals (image and sound) at the same band simultaneously.

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